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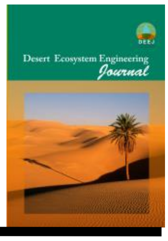

Forecasting Drought in Arid Regions Using Global Climate Models: A Case Study of Yazd Province, Iran

Zohre Arjmandi Herat[1], Mohammad Amin Asadi Zarch[2]*, Seyed Zeynalabedin Hoseini[3], Mohammad Reza Ekhtesasi[4]

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Extended Abstract

Introduction: Due to the low annual precipitation rate and, therefore, the existence of a weak and fragile ecosystem, arid regions are more subject to drought. Moreover, significant fluctuations in the temporal and spatial distribution of precipitation make drought forecasting in these areas a complicated task. Having a dry and fragile climate, Yazd Province has experienced numerous droughts within the past few decades. Therefore, it is highly important to monitor and forecast drought in this region.

Population growth has increased water demand. Moreover, the increase in the concentration of greenhouse gases due to rising fossil fuels consumption has caused global warming and climate change, changing the hydrological cycle components including precipitation patterns (snow and rain). Therefore, climate change has changed the frequency, severity, and duration of droughts in many areas, especially in arid and semi-arid regions.

So far, several indices have been developed to assess drought. This study used the RDI, which is based on precipitation (as system input) and potential evapotranspiration (as output), to estimate the drought. Furthermore, there are several methods for forecasting drought, among which projections of global climate models derived from greenhouse gas emission scenarios are quite common.

Materials and Methods: This study sought to analyze the efficiency of global climate models in predicting drought in arid regions (Yazd Synoptic Station, Yazd, Iran). To this end, 1961 to 2005 was selected as the base period, RDI values of which were imported to downscale the model (SDSM). Moreover, 2006 to 2018 was selected as the forecast period whose data were not imported to the model. Finally, the predictions of the model for the period 2006 to 2018 were compared with the observed RDI values of the same period for time scales of one, three, and six months. Accordingly, first, the climatic data collected from Yazd Synoptic Station (minimum and maximum temperature, relative humidity, sunshine hours, and wind speed) were prepared, and then the potential evapotranspiration (PET) was calculated for the period 1961 to 2018 via FAO-Penman-Monteith method. RDI value for the period 1961 to 2018 was then estimated on a monthly basis.

Moreover, to predict drought through global climate models, CanESM2 global model forecasts were obtained based on the RCP8.5 greenhouse emission scenario from 2006 to 2018 for monthly precipitation, minimum temperature, maximum temperature, average temperature, sunshine hours, wind speed, and relative humidity. Using SDSM statistical downscaling model, the observed data for the period 1961 to 2005 and the projections of the CanESM2 model for the period 2006 to 2018 were downscaled.

On the other hand, the mean surface temperature predictor was used to a downscale minimum and maximum temperatures and sunshine hours. Wind speed and surface-specific humidity predictors were also used to

1MSc in Wateshed Management, Faculty of Natural Resources, Yazd University, Yazd, Iran
2Assistant Professor, Faculty of Natural Resources, Yazd University, Yazd, Iran; amin.asadi@yazd.ac.ir
3Assistant Professor, Faculty of Natural Resources, Yazd University, Yazd, Iran
4Professor, Faculty of Natural Resources, Yazd University, Yazd, Iran
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downscale wind speed and relative humidity outputs, respectively. Furthermore, to increase the accuracy, three predictors of precipitation, surface specific humidity, and mean surface temperature were used to downscale precipitation outputs.

Finally, as for the high spatial and temporal variability of precipitation in arid regions, possible biases in precipitation data were corrected using the Linear Scaling bias correction method, which is based on the average difference between monthly observed time series and GCM historical simulations time series over the same period of the observed series. These differences were then applied to the future GCM simulated climate data to get bias-corrected climate variables.

Results: The results obtained from the application of the FAO-Penman-Monteith method indicated that the variable trend presented by PET values during the study period was mostly induced by changes in wind speed fluctuations. Moreover, downscaled precipitation values showed a more significant error rate than those of the downscaled temperature outputs, probably due to the fact that precipitation values had more variability than the temperature ones, especially in arid climates. On the other hand, the application of the Linear scanning bias correction model showed that the precipitation values downscaled by SDSM for the base period (1961-2005) were overestimated compared to the real precipitation data over the same period. Therefore, the overestimation was corrected using the Linear scanning bias correction method. After correcting the probable precipitation biases and calculating the RDI index, the results suggested that the use of the Linear scanning bias correction model remarkably increased the accuracy of CanESM2 precipitation outputs.
Then, the RDI was calculated by replacing the predicted precipitation and potential evapotranspiration values with the real data in the period 2006 to 2018 by measuring the potential evapotranspiration based on the data mentioned. Accordingly, R2 between real RDI values and the CanESM2-extracted forecasted RDI values for the 2006-2018 period was 0.472 for the 1-month time scale, while R2 was 0.738 and 0.762for for 3 and 6-month time scales, respectively.

Discussion and Conclusion: The results indicated that the model presented a good performance at 3 and 6-month timescales. Moreover, considerable fluctuations in one-month precipitation values resulted in high variability of the one-month RDI time series, decreasing the model's performance at this timescale. Therefore, for projecting precipitation in arid and hyper-arid zones, a bias correction method should be applied to minimize probable biases. Furthermore, the comparison of actual droughts that occurred from 2006 to 2018 with the values predicted by the model at 1, 3, and 6-month time scales showed that the CanESM2 model predicted the drought patterns with relatively good accuracy at 3 and 6-month timescales. However, as for the one-month timescale, the model presented lower efficiency than the other two time scales due to more fluctuations. Therefore, it can be concluded that GCM forecasts have a relatively acceptable efficiency for long-term drought prediction in arid climates.

Keywords: Drought, FAO-Penman-Monteith, Global Climate Models, RDI, SDSM, CanESM2, RCP8.5.